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PROCESS EVALUATION OF A ROTATING BIOLOGICAL
CONTACTOR FOR MUNICIPAL WASTEWATER TREATMENT

Pollution Control Planning Branch
Ministry of the Environment

November, 1974



R.P. W2041

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PROCESS EVALUATION OF A ROTATING BIOLOGICAL
CONTACTOR FOR MUNICIPAL WASTEWATER TREATMENT

By:

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Wastewater Treatment Section
Pollution Control Planning Branch
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Ministry of the Environment
135 St. Clair Ave. W.
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SUMMARY

An evaluation of the aerobic biological treatment process employing a rotating biological contactor (RBC) was conducted on both a continuous feed and an intermittent feed basis using a package type plant treating domestic wastes. From results obtained at a number of different organic loadings during the continuous feed period, it was established that the system could produce a secondary quality effluent (15 mg/l BOD and suspended solids) when the organic load was limited to approximately 1 lb BOD/day/1000 sq ft disc area. Similar results were obtained with an intermittent feed at the same organic load indicating that the treatment system is not adversely affected when operated on an intermittent basis. Sludge accumulations within the system caused no process problems but would require sludge removal approximately every 4 to 6 months on a continuous use basis. No mechanical problems were experienced with the system in one year of operation.

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INTRODUCTION

The rotating biological contactor (RBC) treatment system is an aerobic biological treatment system in which the active bio-mass is retained on a number of large diameter discs rather than in aqueous suspension as in the activated sludge system. Similar micro-organisms are found in both systems. In larger treatment systems the rotating biological contactor replaces the activated sludge system aeration tanks while the primary and final clarifier facilities would be essentially the same. In small package type plants, designs may vary with equipment suppliers with some systems being contained entirely in one partitioned tank and others having individual tanks for each unit process. The use of the RBC process has found its greatest application in Europe and only recently in North America. Most of the early North American applications and process investigations have been directed toward the pretreatment of industrial wastes.

At the request of the Design Approvals Branch of the Sanitary Engineering Division, an evaluation of the RBC process was undertaken in June 1973 principally to investigate the performance and potential operating problems of a package type RBC treatment plant operated under intermittent loading conditions when treating domestic wastes. Because the RBC process is an aerobic biological process, the basis of evaluation of the system was the ability of the process to produce a secondary quality effluent, i.e. 15 mg/l BOD and suspended solids. Included in the evaluation was the consideration of whether the design for these

systems, many of which were developed to satisfy European standards or industrial pretreatment requirements, is adequate to meet waste treatment requirements in the Province of Ontario. The field evaluation of the RBC system, on loan from Ames-Crosta-Mills Ltd., was conducted over a period of approximately one year on a typical domestic waste at the Bolton WPCP.

LITERATURE REVIEW

A brief literature review was conducted as a part of the RBC evaluation to determine the operating experience of existing systems and the design criteria currently in use.

A brief survey conducted by T.W. Beak Consultants Ltd.⁽¹⁾ presents European experience with RBC treatment plants. The six plants investigated received domestic wastes and mixtures of industrial and domestic wastes at organic loadings ranging from 3.5 to 15 lb BOD/day/1000 sq ft of disc surface area. Although percentage organic removals in some cases approached 90%, none of the systems produced a secondary quality effluent.

The Water Pollution Research Laboratory⁽²⁾ investigated the performance of an Ames-Crosta-Mills RBC package type plant in England treating a strong domestic waste. At an organic load on the system of 1.97 lb BOD/day/1000 sq ft disc area and an estimated load on the discs of 1.06 lb BOD/day/1000 sq ft disc area, the system just failed to meet the 20 mg/l BOD and 30 mg/l suspended solids British standard. Sludge removal was estimated to be required every 4 to 6 weeks from the primary tank and every three months from the final tank.

The Water Pollution Research Laboratory⁽³⁾ then conducted additional studies with the same system to determine the effect of diurnal flow variations and higher flows on process performance. At an organic loading rate of 1.7 lb BOD/day/1000 sq ft disc area applied during a 16 hour period, the system met the 20:30 standard.

At the same organic load applied in the same 16 hour period with three peak flow periods at three times the average daily flow, effluent quality deteriorated somewhat, just failing to meet the standard. An organic load of 2.2 lb BOD/day/1000 sq ft applied during a 16 hour period could not be treated to meet the British standards.

Welch⁽⁴⁾, Antonie^(5,6,7,8) and Birks⁽⁹⁾ discuss the features of RBC systems and present limited process performance data for Autotrol RBC systems treating synthetic sewage and dairy wastes. Secondary effluent quality was not achieved in any of these studies whose direction appeared to be oriented towards pretreatment. In a study conducted by Autotrol Corporation⁽¹⁰⁾ process data obtained for an Autotrol prototype package plant operated over a range of disc rotational speeds (2 to 5 RPM) and organic loadings are presented. Because some of the best process performance was achieved at intermediate rotational speeds, the effect of disc rotational speed on process performance does not appear to have been conclusively demonstrated. The process conditions at which an effluent quality of 15 mg/l BOD and suspended solids occurred were at hydraulic loadings of less than 1 gpd/sq ft disc area and at organic loadings up to a maximum of 1.4 lb BOD/day/1000 sq ft.

Antonie⁽¹¹⁾ presents process results for the Pewaukee, Wisconsin 0.5 MGD municipal treatment RBC system design at 2.8 US gpd/sq ft disc area. From the performance data presented, it appears that to produce a secondary quality effluent the hydraulic loading would have to be limited to 0.6 US gpd/sq ft or an organic loading of approximately 0.6 lb BOD/day/1000 sq ft disc area.

Operating data for the 32,000 US gpd RBC treatment plant at Brewster, New York⁽¹²⁾ indicate that for this underloaded plant a secondary effluent quality is produced through two of the four stages corresponding to a hydraulic loading of 0.46 gpd/sq ft and an organic loading of 0.57 lb BOD/day/1000 sq ft disc area.

Torpey⁽¹³⁾ presents results for a pilot RBC system treating domestic sewage. Operating at a hydraulic loading of 2.1 US gal/sq ft and an organic loading of 2.6 lb BOD/day/1000 sq ft, the system produced a secondary quality effluent. However, it is believed that the effluent data presented were for filtered or settled samples and the BOD results were for only the carbonaceous BOD, the nitrification in the BOD tests being suppressed by the addition of allylthiourea.

Sack⁽¹⁴⁾ presents results for an RBC system treating wastes from a recreational camp. At a hydraulic loading of 0.64 gpd/sq ft and an organic loading of 1.35 lb BOD/day/1000 sq ft, a secondary quality effluent was not achieved.

A summary table of process conditions and performance for the above studies is presented in Appendix A. From the results in this table, it appears that a secondary effluent quality cannot normally be expected from an RBC system treating domestic waste when the organic loading exceeds 1 lb BOD/day/1000 sq ft disc area.

DESCRIPTION OF PILOT ROTATING BIOLOGICAL CONTACTOR

The equipment used in the evaluation of the rotating biological contactor treatment system was an individual household unit, on loan from Ames-Crosta-Mills Ltd., designed to treat domestic wastes for a maximum of five persons with a nominal hydraulic load of 300 gpd and a design organic load of 0.75 lb BOD/day. The entire system is contained within one rectangular covered tank approximately 6 1/2 ft long by 5 ft wide with a maximum liquid depth of 3 2/3 ft. The primary treatment, biological treatment, and final clarification zones are provided within this tank by internal partitions. A partition the full width of the tank separates the 59.5 in. by 12 in. final tank from the 59.5 by 66 in. primary tank. The rotating, biological treatment system is contained in a 53 in. by 18 in. radius semi-cylindrical tank located at the surface of the primary tank. The biological treatment tank is divided into five stages, the first two of which have longitudinal 2 inch wide openings in the bottom to permit sludge production from the first two sets of discs to drop into the primary tank. The first two disc compartments being connected to the primary tank, the system is actually a four stage system, the first stage comprised of 16 thirty inch diameter discs in the first two compartments and the remaining three stages each comprised of 8 similar discs. The total disc area is 400 sq ft. The discs, which are rotated at 1 RPM, are

immersed to a depth of 11.25 inches, i.e. 34% of the disc area is submerged. The last biological disc compartment is connected by a 3 inch pipe to the final tank. Baffling is provided around the discharge pipe from the final tank to prevent the discharge of scum and/or floating solids. At the nominal 300 gpd hydraulic load, the 560 gal primary tank has a 1.87 day retention time and an overflow rate of 20 gpd/sq ft. Similarly, the 115 gal final tank has a 0.38 day (9.2 hr) retention time and an overflow rate of 60 gpd/sq ft while the 72 gal disc tank has a retention time of 0.24 days (5.7 hr). Total system retention is 2.5 days (60 hrs) at the nominal 300 gpd capacity.

RBC PROCESS EVALUATION

The evaluation of the RBC system was undertaken primarily to establish process performance under intermittent operating conditions and to determine the nature of operating problems, if any, with both the RBC process and package type plants employing this process. Because the anticipated problems were expected to involve floating sludge and odours as a result of the long sludge age of raw sludge in the primary tank, a long start-up period was required to accumulate sufficient sludge in the primary tank to evaluate the process under representative steady state conditions. Prior to the evaluation under intermittent operating conditions, the performance of the process under continuous flow conditions was established as a basis for comparison. Acceptable performance was based on the maximum organic load at which the system produced secondary quality effluent, i.e. 15 mg/l BOD and suspended solids. The initial start-up performance was also monitored to establish the time required by the system to build up a biological growth and to produce an acceptable effluent quality. Other areas of the evaluation included maintenance, winter operation, sludge production and typical operational dissolved oxygen (DO) concentrations at different operating conditions.

During each set of continuous operating conditions, 24 hr composite samples were taken of the raw sewage feed to the unit and of the final effluent from the final clarifier three or four times a week. Samples were occasionally taken from the primary

tank. Routine analyses on the raw sewage and final effluent included pH, BOD, filtered BOD, suspended solids, volatile suspended solids, ammonia nitrogen, total phosphorus, and soluble phosphorus. In addition to these analyses, nitrate nitrogen analyses were conducted on the final effluent and occasional primary effluent samples.

Start-up

Raw sewage feed to the RBC system was started in the middle of June 1973 at the nominal capacity (300 gpd) of the unit to allow the biological mass to build up on the discs. After approximately three weeks of operation, biological mass had built up on the first three sets of discs but only slightly on the last two sets of discs. It was only after several more months of operation that the last two sets of discs had gradually built up a comparable sludge growth. However, the results from samples taken during the fourth through sixth week of operation presented in Table 1 indicate that a good quality effluent was being produced after a three week start-up. The organic load on the discs during this period averaged approximately 0.42 lb BOD/day or 1.05 lb BOD/day/1000 sq ft disc area. This loading represents approximately 56% of the organic design capacity of the system.

Only partial removal of ammonia nitrogen, approximately 55%, was achieved during this period. The performance during this period indicates the performance capabilities of the discs but not of the system under representative conditions because there was still no measurable sludge accumulation in the primary tank.

TABLE 1
PROCESS PERFORMANCE DURING STARTUP AT 320 GPD

Sample Source	pH	BOD	Suspended Solids	Vol. Suspended Solids	NH ₃ N ³	NO ₃ N ³	Total P	Soluble P
Raw Sewage	7.6	131	276	185	18	-	6.4	4.0
RBC Effluent	7.9	11	8	6	8	10	3.6	2.4

At this time, other research studies being conducted at the Bolton WPCP necessitated a change in the location of the feed pump and piping for the RBC system to prevent the feeding of chemically treated raw sewage to the system. Considerable difficulty was encountered with the re-arranged pumping system resulting in an intermittent feed to the unit during the period in which the system was permitted to acquire a representative accumulation of sludge in the primary tank and build up a biological mass on all of the discs. Analytical results of composite samples taken during this period are presented in Table 2. Effluent quality remained good when the feed to the system was resumed after prolonged shutdown periods. The average organic load on the full days of operating during this period of intermittent operation was approximately 0.45 lb BOD/day or 1.1 lb BOD/day/1000 sq ft. Results during this period were similar to those achieved during the initial start-up period with continuous feed conditions at a similar organic load. Thus, results obtained before a significant amount of sludge had accumulated in the primary tank indicate that intermittent operation did not have an adverse effect on the performance of the biological system.

TABLE 2

PROCESS PERFORMANCE DURING INTERMITTENT OPERATION

Sample Source	pH	BOD	Filtered BOD	Suspended Solids	Vol. Suspended Solids	NH ₃ N ₃	NO ₃ N ₃	Total P	Soluble P
Raw Sewage	7.4	141	45	233	159	33	-	7.0	4.5
RBC Effluent	7.9	10	5	13	11	10	5	3.4	2.0

CONTINUOUS FEED PROCESS EVALUATION

When a sludge depth of approximately 1 to 2 inches had accumulated in the primary tank and after a more reliable raw sewage feed pump was installed, the process evaluation was begun under continuous feed conditions. Each period of evaluation lasted three to four weeks.

The first period of evaluation was conducted at the nominal hydraulic capacity of the system, 300 GPD. Analytical results of composite samples taken during this period are presented in Table 3. The raw sewage strength was weak at this time resulting in a low organic load to the unit. The average organic load was 0.174 lb BOD/day or 0.435 lb BOD/day/1000 sq ft disc area which represents approximately 23% of the design organic load. A secondary quality effluent was produced during this phase of operation although complete nitrification was not achieved. At operating temperatures of 5-10°C, the typical range of operating DO's in disc tank compartments ranged from 1 to 6 mg/l with the lower values occurring in the first two compartments.

In an attempt to operate at the design organic load of approximately 0.75 lb BOD/day, the feed rate was increased to 1280 gal/day. This increased the overflow rate in the primary tank to 80 gal/day/sq ft from 20 gal/day/sq ft and in the final tank from 60 to 240 gal/day/sq ft. The retention time in the biological treatment zone was reduced from 5.4 hrs to 1.3 hrs. Results for this period of operation in which the average organic load was 1.1 lb BOD/day or 2.75 lb BOD/day/1000 sq ft disc area are presented in Table 4. The operating temperature during this phase of operation

TABLE 3

PROCESS PERFORMANCE AT 320 GPD

Sample Source	pH	BOD	Filtered BOD	Suspended Solids	Vol. Suspended Solids	NH ₃ N ₃	NO ₃ N ₃	Total P	Soluble P
Raw Sewage	7.5	55	21	117	79	17	-	4.6	2.0
RBC Effluent	7.6	6	7	8	6	4	9	2.5	1.9

TABLE 4

PROCESS PERFORMANCE AT 1280 GPD

Sample Source	pH	BOD	Filtered BOD	Suspended Solids	Vol. Suspended Solids	NH ₃ N ₃	NO ₃ N ₃	Total P	Soluble P
Raw Sewage	7.5	87	39	116	66	14	-	4.6	2.0
RBC Effluent	7.6	41	17	28	18	13	2	3.6	2.0

ranged from 8 to 15°C while the DO's in the biological treatment compartments ranged from 0.5 to 3 mg/l with low DO's occurring in the first three compartments. The results in Table 4 indicate that the system, operating at 45% above its design load, was organically overloaded.

The load on the unit was reduced by reducing the hydraulic load to 960 gal/day. This resulted in an organic load of 0.77 lb BOD/day or 1.93 lb BOD/day/1000 sq ft. This organic load represents the design load for this system. Results presented in Table 5 indicate that the system was still organically overloaded. At a range of operating temperatures from 12 to 15°C, the DO's in the biological treatment zones ranged from 0 to 2.7 mg/l with the DO's in the first three biological compartments normally less than 1 mg/l and in the first two compartments frequently at 0 mg/l, further indicating the organic overload.

An attempt was made to further reduce the organic load on the system to its treatment capability by reducing the daily flow to 640 gpd. However, the sewage strength increased during this period resulting in an average daily organic load of 0.77 lb BOD/day, the same as the previous test period and still at the design organic load. Results presented in Table 6 confirm that at an organic loading of 1.93 lb BOD/day/1000 sq ft, the biological system is organically overloaded even with an increased retention time. At an operating temperature of 16 to 18°C, the DO's in the biological tank were consistently less than 1 mg/l again indicating the organic overload.

TABLE 5

PROCESS PERFORMANCE AT 960 GPD

Sample Source	pH	BOD	Filtered BOD	Suspended Solids	Vol. Suspended Solids	NH ₃ N ₃	NO ₃ N ₃	Total P	Soluble P
Raw Sewage	7.5	81	31	159	84	19	-	5.0	2.8
RBC Effluent	7.7	22	7	16	13	16	2	3.7	2.8

TABLE 6

PROCESS PERFORMANCE AT 640 GPD

Sample Source	pH	BOD	Filtered BOD	Suspended Solids	Vol. Suspended Solids	NH ₃ N ₃	NO ₃ N ₃	Total P	Soluble P
Raw Sewage	7.5	122	42	140	93	20	-	5.3	3.0
RBC Effluent	7.8	34	17	13	10	17	1	4.2	3.6

With the increased sewage strength, the flow was further reduced to the nominal hydraulic capacity of 300 gpd to attempt to load the system to its maximum treatment capability. Results for this period during which the average daily organic load was 0.33 lb BOD/day or 0.83 lb BOD/day/1000 sq ft disc area are presented in Table 7. These results indicate that a secondary quality effluent was produced although complete ammonia removal was not achieved. However, a significant conversion of ammonia to nitrate was occurring at this organic loading whereas it had not been at higher organic loadings. At operating temperatures between 17 and 19°C, the DO's in the first two biological zones ranged from 0.5 to 1.0 mg/l and in the last three zones from 0.8 to 1.4 mg/l. The process performance and operating DO's during this evaluation period indicate that the system was operating at or near its maximum capability.

From the results obtained during this last continuous feed period and during the start up period, it appears that the maximum design loading should be limited to approximately 1 lb BOD/day/1000 sq ft disc area. The corresponding hydraulic loading is approximately 0.8 gpd/sq ft disc area for the sewage strength encountered at the Bolton WPCP. The corresponding volumetric organic loading for the disc tank is approximately 35 lb BOD/day/1000 cu ft disc tank volume, which is the same as conventional activated sludge volumetric loadings. For the system evaluated, the volume of disc tank per unit area of disc was 0.18 gal/sq ft

TABLE 7

PROCESS PERFORMANCE AT 320 GPD

Sample Source	pH	BOD	Filtered BOD	Suspended Solids	Vol. Suspended Solids	NH ₃ N ³	NO ₃ N ³	Total P	Soluble P
Raw Sewage	7.8	104	36	133	100	21	-	5.5	2.8
RBC Effluent	7.6	16	6	7	6	6	8	4.1	3.2

disc area. The effluent quality for each of the continuous flow evaluation periods with the corresponding organic loadings are summarized in Table 8.

The effect of organic loading on the effluent quality with the corresponding hydraulic conditions for each organic load is also illustrated in Figure 1. In order to obtain the desired organic load, it was necessary to alter the sewage flow because of different sewage strengths during different study periods. At the nominal hydraulic capacity of the unit, a secondary quality effluent was just achieved at approximately 1 lb BOD/day/1000 sq ft disc area under both continuous and intermittent feed conditions with a representative sludge accumulation. During start-up and at a lower organic load, the performance at the nominal hydraulic capacity was somewhat better. During two study periods at the design organic load, hydraulic rates of two and three times the nominal hydraulic capacity were used, representing hydraulic overload factors normally used for activated sludge plant designs but still providing adequate detention times for the biological system. The low effluent suspended solids, the low DO in the disc tank, and the failure to achieve 15 mg/l effluent BOD's in both periods was interpreted as indications of an organic overload rather than a hydraulic overload of the system. The study period with an organic load in excess of the design organic load was conducted at four times the nominal hydraulic rate. The high effluent suspended solids with the high effluent BOD suggests that the system may have been hydraulically as well as organically overloaded.

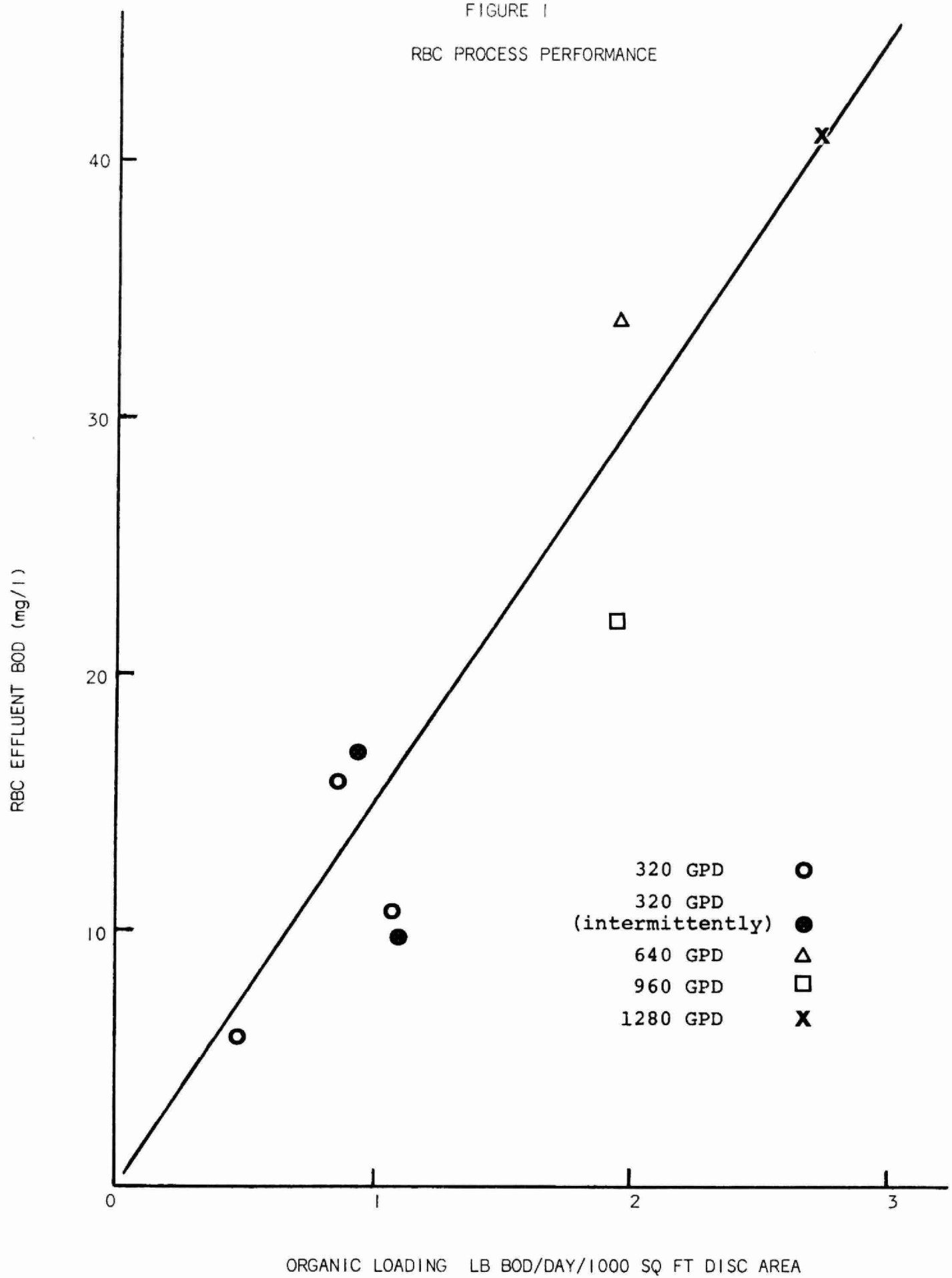
TABLE 8

RBC PROCESS PERFORMANCE SUMMARY

Flow IGPD	Disc Tank Retention (hr)	<u>Organic Loading</u>			<u>Effluent Quality</u>					
		lb BOD/ day	lb BOD/ day/ 1000 sq ft disc area	lb BOD/ day/ 1000 cu ft disc tank	BOD	Suspended Solids	NH ₃ N ³	NO ₃ N ³	Operating DO Range mg/l	Temperature Range °C
320*	5.4	0.42	1.05	37	11	8	8	10	-	-
1280	1.3	1.1	2.75	96	41	28	13	2	0.5 - 3	8 - 15
960	1.8	0.77	1.93	67	22	16	16	2	0 - 2.7	12 - 15
640	2.7	0.77	1.93	67	34	13	17	1	0 - 1	16 - 18
320	5.4	0.17	0.44	15	6	8	4	9	1 - 6	5 - 10
320	5.4	0.33	0.83	29	16	7	6	8	0.5 - 1.4	17 - 19
320* (Intermittent)	5.4	0.45	1.1	40	10	13	10	5	-	-
320 (Intermittent)	5.4	0.37	0.92	32	17	6	3	8	0 - 4.2	18 - 21

* Startup Period

FIGURE 1
RBC PROCESS PERFORMANCE



INTERMITTENT OPERATION

Following the continuous feed period of the evaluation in which the organic loading capacity of the RBC system was established and a representative sludge accumulation developed, the performance of the system under intermittent feed conditions was evaluated. Raw sewage was fed to the unit two consecutive days per week for a six week period. With a similar sewage strength to that experienced during the last phase of the continuous feed period, the feed rate of 320 gpd for the two days that the unit was fed produced an average organic loading of 0.92 lb BOD/day/1000 sq ft disc area during the evaluation. This loading was established as approximately the maximum capacity of this system during the continuous feed period. Results presented in Table 9 for this phase of the evaluation indicate similar results to those obtained during the continuous feed period. Thus, it appears that the organic removal efficiency of the unit is not adversely affected by intermittent feed conditions. Operating temperatures during this period ranged from 18 to 21°C. DO concentrations ranged from 0 to 1.1 mg/l in the first two biological compartments and from 0.7 to 4.2 mg/l in the last three compartments when the unit was being fed. These DO concentrations indicate that system was operating near its maximum loading while still able to maintain aerobic conditions. When the feed was discontinued, the DO increased in all stages, but more-so in the last three stages. When the feed was resumed, DO levels dropped within hours to the normal operating concentrations.

TABLE 9

PROCESS PERFORMANCE AT 320 GPD (TWO DAYS PER WEEK)

Sample Source	pH	BOD	Filtered BOD	Suspended Solids	Vol. Suspended Solids	NH ₃ N ₃	NO ₃ N ₃	Total P	Soluble P
Raw Sewage	7.7	115	48	136	110	22	-	5.5	3.3
RBC Effluent	7.7	17	8	6	5	3	8	4.8	3.7

Samples taken from the primary tank prior to the weekly two day feed period show the presence of nitrate and a lower than normal ammonia concentration indicating the recirculation of flow from the first two disc compartments into the primary tank. The soluble BOD for the primary tank during both the continuous and intermittent feed periods were lower than or equal to the raw sewage BOD's indicating that if there was any solubilization of organic matter in the primary sludge, it was not increasing the organic load on the discs. It was noticed that following approximately one week without feed, the liquid level in the isolated two centre disc compartments had dropped approximately two inches due to evaporation. A lesser drop was noted for the first two compartments which are connected to the primary tank and for the last compartment which is connected to the final tank. During an extended period without feed the liquid level could drop sufficiently to permit the biological growth on the discs to dry out. Process performance during startup could be adversely affected after such a prolonged shutdown although the startup time is expected to be less than the original two to three week period.

WINTER OPERATION

The package type plant used for the evaluation of the RBC process would normally have been buried at grade level in a permanent installation but for this study the system was completely above grade level. To minimize heat loss during the winter, the sides of the tank were insulated with 2 inches of styrofoam. The 950 watt radiant heater provided with the unit was operated continuously throughout the winter. No process or operating problems were experienced throughout the winter. The minimum temperature encountered in the unit with a raw sewage feed rate of 320 gpd was 4°C. Process performance remained good during the winter even under conditions of intermittent operation. In applications where intermittent winter operation is the normal operating condition, a sufficient heat input to prevent freezing should be provided. The package type plant used for the evaluation was covered and it is assumed that all RBC system designs have the discs covered or enclosed in a building. Failure to do so could result in ice formation on the discs and both structural damage and process failure.

SLUDGE PRODUCTION AND REMOVAL

Sludge accumulation in the primary tank prior to the continuous flow evaluation period was approximately 1 to 2 inches. After treating approximately 70,000 gal of raw sewage, some of which was passed through 1/4 inch screening during the continuous flow study period of 6 months, the sludge accumulation in the primary tank was approximately 6 inches near the sides of the primary tank. The sludge depth beneath the first two disc compartments was approximately 10 to 12 inches. The source of the accumulation in the primary tank cannot be attributed solely to primary sedimentation because the openings in the bottom of the first two disc compartments permit excess sludge sloughing off of these discs to drop into the primary tank. This source of sludge was substantial as evidenced by the greater sludge depths beneath the disc tank. Excess sludge from the last three disc compartments is carried into the final clarifier where it accumulates. The suspended solids concentration of the sludge removed through the drain in the primary tank was measured as 4.8%. A sludge sample siphoned from the final tank was measured as 5.25% solids. To obtain a more representative indication of sludge production, both the primary tank and the final clarifier liquid supernatants were drained leaving mainly the sludge following the intermittent feed evaluation period. The remaining sludge in each compartment was thoroughly mixed and sampled. The 142 gal of sludge in the primary tank at 3.34% solids represents 47 lb of solids while the 44 gal of sludge in the final tank at 2.91% solids represents 13 lb of solids. The solids concentration of these sludge samples is less

than the first set mentioned above because all of the supernatant could not be removed from each of the tanks, thus the sludge was diluted when the remaining contents were mixed. The solids in the primary tank represents approximately 40% of the solids in the raw sewage feed. The total solids accumulation in the system, including the estimated 6 to 10 lbs of solids on the discs, represents approximately 60% of the applied accumulation. The remaining portion of this discrepancy could be accounted for by aerobic digestion of solids on the discs and to some extent by sampling error. The total solids accumulation in terms of the applied BOD load is approximately 65%.

Sludge accumulation in both tanks of the RBC unit averaged approximately 7 inches and represented 15% of the capacity of the tanks. Although these accumulations created no process problems or nuisance problems, such as floating sludge, gassing, or odours, it is felt that further accumulations would represent too great a proportion of the useful tank volumes and that sludge wasting should be carried out when such accumulations occur. Sludge removal from the primary tank is accomplished through a valved outlet in the bottom of the unit, although to remove the sludge from the primary tank it is felt that with the absence of sludge scrapers to move the sludge to the drain the entire tank would have to be drained and possibly flushed out. No drain line is provided for the secondary clarifier tank which would also have to be pumped out completely to remove the accumulated sludge.

From the accumulations experienced during this study, sludge removal would be required every 4 to 6 months on a continuous use basis and would be advisable at the end of the season on a seasonal use basis.

The raw sewage used for the evaluation of the RBC system was taken within the Bolton WPCP after grit removal. Thus, the accumulations measured in this study are probably lower than would be experienced for individual household units although the sludge removal frequency suggested above would likely be adequate.

GENERAL OPERATING CONDITIONS

Throughout the period of evaluation, the anticipated potential problem areas of odours, floating sludge, flies and mechanical failures were not experienced. Scum formation was noticed on the final clarifier tank and in small areas on the primary tank. The baffling provided around the discharge pipe prevented the carryover of any of this material in the final effluent. The only maintenance performed on the unit throughout the evaluation period was a change of the lubricating oil in the open gear box. Although the mechanical reliability of the equipment appears to be good, it is felt that an alarm system or warning signal should be provided in case of motor or other drive component failures for package plant installations that would be unsupervised.

The evaluation of the RBC system was conducted without facilities for phosphorus removal. Phosphorus removal during the evaluation ranged from 21% to 51%, principally due to solids removal. The higher soluble phosphorus concentrations in the effluent than in the feed during the latter part of the evaluation could be due to solubilization of phosphorus in the accumulated sludge. No process problems are anticipated with phosphorus removal facilities using prime coagulants such as alum or ferric chloride, except for the increased sludge production of approximately 20 to 30%.

DISC BIOLOGICAL GROWTH

Microscopic examinations of the biological growth on the discs revealed the presence of not only typical micro-organisms normally found in conventional activated sludge systems, but also significant quantities of filamentous bacteria. The filamentous growth did not cause operating problems because it is retained on the discs. There was also a difference in the predominant species present in each disc compartment with greater quantities of the higher life forms such as protozoans and nematodes occurring in the latter treatment stages.

Following completion of the intermittent feed evaluation, samples of the biological growth were taken from each set of discs approximately one week after the feed was discontinued. The dry weight of biological mass on the discs estimated from these samples varied from 0.16 lb on the second set of discs to 2.2 lb on the third set of discs. The solids concentration was fairly consistent with a range of 6.6% to 7.7% and the volatile fraction ranged from 63% on the fourth set of discs to 94% on the second set of discs. For the disc tank volume of 72 gal, the total weight of biological solids on the discs of 6.27 lb would be equivalent to a mixed liquor suspended solids concentration of 8700 mg/l. With continuous feed conditions, the weight of biological mass in the system will be slightly greater than was measured during the no-feed period. It was noticed that following

a period without feed the biological mass began to slough off of the discs. With the maximum daily load of 0.4 lb BOD and a total biological mass of approximately 6-10 lb, the system would operate at a F/M ratio of approximately 0.05, i.e. at an organic loading equivalent to that used for extended aeration type plants. However, the volumetric organic loading of 35 lb BOD/day/1000 cu ft disc tank represented by the 0.4 lb BOD/day organic loading is equivalent to a conventional activated sludge plant design loading. Thus, the RBC system can be thought of as a conventional activated sludge system operating with a very high mixed liquor suspended solids concentration. The problems that would be associated with such a mixed liquor system (final clarification of a 10,000 to 15,000 mg/l MLSS) are avoided by maintaining the solids in a more concentrated (70,000 mg/l) fixed growth on the discs.

CONCLUSIONS

1. The RBC treatment system can produce a secondary quality effluent when the organic load is limited to approximately 1 lb BOD/day/1000 sq ft disc area.
2. Process performance is not adversely affected when the system is operated on an intermittent basis.
3. Substantial quantities of sludge accumulation in both the primary and final tank did not result in any nuisance or process problems.
4. For package type RBC systems, sludge removal will be required approximately every 4 to 6 months on a continuous use basis. Unless sludge scraper mechanisms are provided, the entire tank contents would have to be emptied at times of sludge removal.
5. The process performance of the RBC system was not adversely affected by temperature. It is assumed that, like the unit evaluated, all RBC system designs have the discs covered or enclosed in a building and that a sufficient heat input is provided to prevent freezing for small units operated intermittently during the winter.

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APPENDIX A

RBC PERFORMANCE SUMMARY

Location	Equip. Supp.	Flow IGPD	DISC PARAMETERS			DISC TANK		DISC LOADING		BOD (mg/l)		SS (mg/l)		NH ₃ -N		NO ₃ -N	
			Area sqft	Dia. ft	Peri- pheral Speed ft/min	Ret. hr.	gal/ sqft	IGPD sqft	lb BOD day 1000 sq ft	Infl.	Effl.	Infl.	Effl.	Infl.	Effl.	Infl.	Effl.
Jamaica WPCP, NYC	-	9,900	6,800	3	94	0.92	0.056	1.25	1.8	124 ^(a)	9 ^(a,b)	107	9	13	5.7	10.4	
			4,750	3	94	0.64	0.056	1.75	2.6	124 ^(a)	14 ^(a,b)	107	14	13	11	4.3	
Camp Horseshoe, W.Va.	-	3,730	5,800	6.5	41	8.25	0.187	0.64	1.35	210	32	31	8	41.3	30.9	5.7	
Stevenage, Eng.	ACM	600	1,690	3.28	10.3	6.1	0.091	0.35	1.06	219	24	185	30	48.1	27.3	10.7	
		600/ 16 hrs.	1,690	3.28	10.3	4.1	0.091	0.35	0.78	220	14	171	21	39	15.8	13.1	
		800/ 16 hrs.	1,690	3.28	10.3	3.1	0.091	0.47	1.4	305	28	278	35	45.6	32.6	5.4	
Brewster, N.Y.	Auto- trol	4,800	21,000					0.23	0.28	123	6 ^(b)	-	-	27.8	0.6	18.9	
			10,500					0.46	0.56	123	8 ^(b)	-	-	27.8	2.9	16.3	
Pewaukee, Wisc.	Auto- trol	50,000	63,000	10	63			0.8	0.93	118	12	-	-	14.1	0.6	-	
Pewaukee, Wisc.	Auto- trol	1,000	4,600	5.75	90	14	0.127	0.22	0.24	112	12	107	12	12	0	10	
		2,500	4,600	5.75	58	5.6	0.127	0.54	0.56	104	22	96	24	13.8	1.3	8.2	
		2,100	4,600	5.75	90	6.7	0.127	0.46	0.78	170	19	124	19	16	1	9	
		3,900	4,600	5.75	36	3.6	0.127	0.85	1.1	127	18	100	15	17.4	2.7	7.9	
		3,760	4,600	5.75	85	3.7	0.127	0.82	1.2	147	15	114	13	23	1.3	16	
		4,300	4,600	5.75	58	3.3	0.127	0.93	1.3	139	30	190	33	19.4	8.8	5.2	
		4,120	4,600	5.75	58	3.4	0.127	0.90	1.42	158	15	107	11	19.5	1.6	12	
		4,100	4,600	5.75	90	3.4	0.127	0.89	1.55	175	22	183	74	26	19	3	
		4,100	4,600	5.75	90	3.4	0.127	0.89	1.7	192	30	84	16	16	12	6	
		6,300	4,600	5.75	58	2.2	0.127	1.37	1.86	138	19	150	27	16.5	4.5	10.4	
		5,700	4,600	5.75	83	2.5	0.127	1.25	1.9	155	21	91	16	22.1	3.6	10.8	
		6,000	4,600	5.75	36	2.3	0.127	1.3	2.5	190	28	229	30	35.6	16.2	-	

RBC PERFORMANCE SUMMARY

Location	Equip. Supp.	Flow IGPD	DISC PARAMETERS			DISC TANK		DISC LOADING		BOD (mg/l)		SS (mg/l)		NH ₃ -N		NO ₃ -N
			Area sqft	Dia. ft	Peri- pheral Speed ft/min	Ret. hr	gal/ sqft	IGPD sqft	lb BOD day 1000 sq ft	Infl.	Effl.	Infl.	Effl.	Infl.	Effl.	Effl.
Pewaukee, Wisc.	Auto- trol	10,100	4,600	5.75	36	1.4	0.127	2.2	2.75	125	34	82	24	16.6	11.2	1.5
		8,300	4,600	5.75	90	1.7	0.127	1.8	3.3	183	34	152	76	22.6	18.2	0.17
		9,700	4,600	5.75	90	1.45	0.127	2.1	4.3	205	37	144	34	14.1	10	0.11
		18,400	4,600	5.75	58	0.76	0.127	4.0	5.1	128	44	138	49	14.0	12.0	0.4
		18,000	4,600	5.75	81	0.77	0.127	3.9	5.4	139	53	94	38	17.3	15.9	-
DePere, Wisc.	Auto- trol	2,500	13,800	10	63	8.0	0.06	0.18	1.8	-	-	-	-	-	-	-
									0.9*	1062	42	-	-	-	-	-
Kappelroedeck, W.Ger.	Stenge- lin	500,000	196,000	9.83	31	7.85	0.835	3.1	4.5	175	25	-	-	19.3	13.4	-
Urloffen, W.Ger.	"	284,000	1,169,000	9.83	39	0.8	0.081	2.43	15	620	70	-	-	29.5	30.8	30
Spalt, W. Ger.	"	284,000	220,000	9.83	31	1.26	0.07	1.29	4.75	370	46	-	-	23.8	14.4	3.4
Amberieu en Bugey, Fr.	TEBA (Stengelin)	1,060,000	302,000	9.83	46.5	0.82	0.12	3.5	9.45	270	38	-	-	-	-	0.5
Leidersdorf, Den.	Lief Holmberg	1,900	2,680	4 ft 38 mm balls	31	-	-	0.71	7.5	-	-	-	-	-	-	-
Bad Durrheim	Stenge- lin	760,000	278,000	9.83	31	0.72	0.815	3.35	8.8	-	-	-	-	-	-	-

* Estimated

(a) Filtered BOD

(b) ATU BOD's

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